

**(12) Official Gazette for Unexamined Patents (A)**

(11) Kokai Patent No. Hei 5(1993)-311,292

(43) Kokai Date: November 22, 1993

(51) Int. Cl.<sup>5</sup>: Identification Symbols: Internal File No.: FI:  
C 22 C 9/04  
C 22 F 1/08 K

Request for Examination: Not Requested

**Number of Claims: 4**

**(Total of 6 Pages)**

(54) COPPER-BASE ALLOY FOR HEAT EXCHANGERS AND  
A METHOD OF PRODUCING THE SAME

(21) Application No. Hei 4(1992)-139,894

(22) Application Date: May 1, 1992

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(57) [Abstract]

[Purpose] The purpose is to present a copper-base alloy for heat exchangers that is capable of satisfying the recent industrial demands of light weight and high reliability of light-weight parts in automobiles, etc., and a method for its production.

[Structure] The structure is a copper base alloy consisting, in terms of wt%, of 15.6 wt% Zn, 0.98 wt% Ni, 0.90% Sn, and 0.05% P, with the total of Ni and Sn being 1.88%, the ratio of Ni/P in terms of wt% being 19.6, and the remainder being Cu and unavoidable impurities. Crystal particle diameter is 0.025 mm, tensile strength is 37.0 kgf/mm<sup>2</sup>, elongation is 40.3%, and the Erichsen value is 14.3 mm. [The alloy] shows good stress-related corrosion and cracking resistance in ammonia vapor and degraded L.L.C. and is an ideal material for heat exchangers.

[Scope of Patent Claim]

[Claim 1] A copper base alloy for heat exchangers, comprising, in terms of wt%, 8 to 20% Zn, 0.3 to 1.5% Ni, 0.3 to 1.2% Sn, and 0.005 to 0.20% P, with the total wt% Ni and wt% Sn being 0.8 to 2.5 wt%, the ratio of the wt% of Ni/P being within a range of 5 to 50, and the remainder being Cu and unavoidable impurities.

[Claim 2] The copper-base alloy for heat exchangers according to claim 1, wherein crystal particle diameter is 0.005 to 0.030 mm.

[Claim 3] The copper-base alloy for heat exchangers according to claim 1 and claim 2, wherein tensile strength is 35 kgf/mm<sup>2</sup> or greater and the Erichsen value is 10 mm or higher.

[Claim 4] A method of producing a copper base alloy for heat exchangers, characterized in that an alloy material, which comprises, in terms of wt%, 8 to 20% Zn, 0.3 to 1.5% Ni, 0.3 to 1.2% Sn, and 0.005 to 0.20% P, with the total wt% Ni and wt% Sn being 0.8 to 2.5 wt%, the ratio of the wt% of Ni/P being within a range of 5 to 50, and the remainder being Cu and unavoidable impurities, is recrystallized, final annealing of this recrystallization product is performed, it is then cold drawn at a percentage reduction in plate thickness of 1 to 15%, and then low-temperature annealing is conducted for 5 to 600 seconds at a temperature of 100 to 400°C.

[Detailed Description of the Invention]

[0001]

[Industrial field of application]

The present invention relates to a copper-base alloy for heat exchangers that is ideal and very reliable as an industrial material, such as used in automobile radiators, etc., and for home heat exchangers, and a method of producing the same.

[0002]

[Prior art]

Copper-base alloys have been used in the past for automobile radiators and in various industries, as well as in home heat exchangers. They are mainly used in tanks, plates, tubes, and lines of automobile radiators, and soft copper-base alloys that are strong and have excellent workability, which are referred to as brass type 1 or brass type 2, are used for tanks, plates and tubes in particular.

[0003]

In recent years there has been a strong demand for lightweight automobiles and high-reliability materials. As a result, there is a need for individual automobile parts that are lightweight and of high reliability. Nevertheless, de-zincing corrosion and stress-related corrosion and cracking occur with the brass materials referred to as brass type 1 or brass type 2 that are being used in the above-mentioned automobile radiators, and therefore, there have been problems in terms of reliability. Moreover, workability is necessary for lightweight parts. This has also resulted in a strong need for improved strength.

[0004]

The de-zincing corrosion and stress-related corrosion and cracking that are seen with automobile radiators which use brass appear to occur for the following reasons: radiators are usually corroded by the  $\text{SO}_2$ ,  $\text{NO}_x$ , and  $\text{Cl}_2$  gases in air after forced cooling of the radiator with air. Moreover, snowmelt ( $\text{NaCl}$ , etc.) and water enter the engine compartment to form a corrosive environment. Furthermore, when coolant is circulated throughout the radiator over long periods of time, corrosive products and contaminants are produced. As a result, the life of the battery is shortened because of the differential aeration cell that is produced when these corrosive substances and contaminants accumulate, there is de-zincing corrosion and particle boundary corrosion and holes are made from the inside as a result of impact corrosion by the circulating liquid, etc.

[0005]

In addition, the long-life coolant (L.L.C.) contained in the above-mentioned radiator must be frequently replaced because of a reduction in the anti-rust agent concentration of the coolant and corrosion by eluted metal ions. Furthermore, the residual stress produced when the alloy is worked and the stress that is applied with caulking, etc., during assembly, in combination with the corrosive environment, leads to stress-related corrosion and cracking. As a result, there are major problems, including leaking of coolant, etc.

[0006]

[Problems to be solved by the invention]

The object of the present invention is to solve the problems of the prior art by presenting an inexpensive copper-base alloy for heat exchangers with excellent corrosion resistance, such as stress-related corrosion and cracking resistance, etc., as well as excellent strength, durability, workability, and solderability.

[0007]

[Means for solving problems]

The present inventors performed intense studies to solve the above-mentioned problem and as a result, they completed the present invention upon discovering that the corrosion resistance of brass, particularly stress-related corrosion and cracking resistance, can be vastly improved, and properties including strength and durability, workability, etc., can be improved, by specifying the Zn content contained in conventional brass materials and adding Ni, Sn and P as needed in specific proportions.

[0008]

That is, the present invention first presents a copper-base alloy for heat exchangers, comprising, in terms of wt%, 8 to 20% Zn, 0.3 to 1.5% Ni, 0.3 to 1.2% Sn, and 0.005 to 0.20% P, with the total wt% Ni and wt% Sn being 0.8 to 2.5 wt%, the ratio of the wt% of Ni/P being within a range of 5 to 50, and the remainder being Cu and unavoidable impurities.

[0009]

Moreover, it is possible to obtain the above-mentioned copper-base alloy for heat exchangers as an alloy with a crystal particle diameter of 0.005 to 0.030

mm. When this condition is satisfied, the alloy is further preferred as a copper-base alloy for heat exchangers. Moreover, it can be obtained as an alloy with a tensile strength of 35 kgf/mm<sup>2</sup> or greater. Furthermore, it can also be obtained as an alloy with an Erichsen value of 10 mm or higher.

#### [0010]

The present invention secondly presents a method of producing a copper-base alloy for heat exchangers, characterized in that an alloy material, which comprises, in terms of wt%, 8 to 20% Zn, 0.3 to 1.5% Ni, 0.3 to 1.2% Sn, and 0.005 to 0.20% P, with the total wt% Ni and wt% Sn being 0.8 to 2.5 wt%, the ratio of the wt% of Ni/P being within a range of 5 to 50, and the remainder being Cu and unavoidable impurities, is recrystallized, final annealing of this recrystallization product is performed, it is then cold drawn at a percentage reduction in plate thickness of 1 to 15%, and then low-temperature annealing is conducted for 5 to 600 seconds at a temperature of 100 to 400°C.

#### [0011]

##### [Effects]

The reasons for restricting the alloy components and the effects of the present invention are described below:

#### [0012]

Zn has the effect of improving strength, workability and the heat-resistant adhesion of the soldered parts. These effects are insufficient when the Zn content by wt% is less than 8%, while if [the Zn content] exceeds 20%, dezincing corrosion and stress-related corrosion and cracking will readily occur,

even if Ni, Sn, and P are present. (Moreover, if the Zn content exceeds 20% in the presence of Ni, Sn, and P, side cracking will readily occur with hot drawing.) Therefore, the Zn content of the present invention was set at a range of 8 to 20 wt%.

[0013]

Ni has the effect of improving strength, durability, heat resistance, and stress-related corrosion and cracking. These effects are insufficient if the Ni content by wt% is less than 0.3%, while if [the Ni content] exceeds 1.5%, workability becomes poor. Therefore, the Ni content of the present invention is set at a range of 0.3 to 1.5%.

[0014]

Sn has the effect of improving strength, de-zincing corrosion resistance, and stress-related corrosion and cracking resistance. These effects are insufficient if the Sn content by wt% is less than 0.3%, while if [the Sn content] exceeds 1.2%, hot workability changes for the worse. Therefore, the Sn content of the present invention is set at a range of 0.3 to 1.2%.

[0015]

Moreover, adding both the abovementioned Ni and Sn has the effect of improving stress-related corrosion and cracking resistance in degraded L.L.C. (There is a marked reduction in anti-rust agent and the amount of eluted metals is marked in degraded L.L.C. that has actually been recovered from automobiles.) However, this effect is insufficient if the total amount of Ni and Sn by wt% is less than 0.8 wt%, while if it exceeds 2.5%, hot workability and cold



workability deteriorate. Therefore, the total Ni and Sn content of the present invention is set at a range of 0.8 to 2.5 wt%.

[0016]

P has the effect of improving melt casting performance, de-zincing corrosion resistance and durability. These effects are insufficient when the P content by wt% is less than 0.005%, while if [the P content] exceeds 0.20%, stress-related corrosion and cracking readily occurs and there is also a reduction in hot workability. Therefore, the P content of the present invention is set at a range of 0.005 to 0.20 wt%.

[0017]

Moreover, In addition to improving strength, durability, heat resistance and stress-related corrosion and cracking by adding both the above-mentioned Ni and P to form an Ni-P compound, the crystal particles become finer with recrystallization. However, it is confirmed that the ratio of Ni/P by wt% with which these effects can be maximized is within a range of 5 to 50.

[0018]

Furthermore, there is a strong correlation between the above-mentioned Ni, Sn and P content. That is, when the Zn content is reduced, there is a reduction in susceptibility to de-zincing corrosion and stress-related corrosion and cracking. However, the strength is insufficient and therefore, more Ni, Sn and P must be added. This addition of more Ni, Sn and P is a disadvantage in terms of production because there is a reduction in melt fluidity during casting, there is an increase in deformation resistance or a reduction in deformation

capability during both hot and cold working, a film forms with heat treatment, etc. Consequently, the minimum Ni, Sn, and P contents (Ni: 0.3 to 1.5 wt%, Sn: 0.3 to 1.2 wt%, and P: 0.005 to 0.20 wt%) and the Zn content that satisfies the properties (8 to 20 wt%) are the optimum contents.

[0019]

Strength and stress-related corrosion and cracking resistance are improved with a finer crystal particle diameter, but deep drawing and overhang workability are reduced. Therefore, a crystal particle diameter of 0.005 mm or larger is desirable. However, if it exceeds 0.030 mm, there is a marked reduction in strength and stress-related corrosion and cracking resistance and a rough surface readily forms after molding. Consequently, the crystal particle diameter of the present invention is set at a range of 0.005 to 0.030 mm.

[0020]

A tensile strength of 35 kgf/mm<sup>2</sup> or greater and an Erichsen value of 10 mm or higher are necessary in order to obtain thin tanks, plates, and lines for radiators. A tensile strength of 36 kgf/mm<sup>2</sup> or greater and an Erichsen value of 11 mm or higher are preferred because of the recent demand for light weight. Moreover, if neither strength or workability are good, it will be difficult to obtain a lightweight radiator. Furthermore, the above-mentioned improvement in corrosion resistance makes it possible to obtain thin parts.

[0021]

The copper-base alloy of the present invention that has been adjusted to the above-mentioned composition shows a marked improvement in stress-

related corrosion and cracking resistance because an Ni-P compound has been formed and segregation of the impurities at the crystal particle boundary is controlled by the effects of the solid Ni and Sn. Therefore, [the copper base alloy of the present invention] has all of the properties required for tanks, plates, and lines of radiators. Moreover, the above-mentioned properties can be efficiently realized by controlling the production conditions as needed during hot drawing and cold drawing of the ingot until it is worked to the desired plate thickness. The details of the method of producing the copper-base alloy of the present invention are explained in detail below:

[0022]

First, an alloy comprising, by wt%, 8 to 20% Zn, 0.3 to 1.5% Ni, 0.3 to 1.2% Sn, and 0.005 to 0.20% P, with the total of the wt% of the above-mentioned Ni and wt% of [the above-mentioned] Sn being 0.8 to 2.5 wt%, the ratio of the wt% of Ni/P being within a range of 5 to 50, and the remainder being Cu and unavoidable impurities, is made into an ingot by melt casting. Furthermore, it is desirable that melt casting be conducted in an inert gas atmosphere. Next, the ingot is hot drawn to obtain a heated and pressed plate and de-burring is performed.

[0023]

Next, after reducing plate thickness as needed by cold drawing, interim annealing is performed to obtain recrystallization. Furthermore, annealing will be insufficient and there will be a reduction in final stress-related corrosion and cracking resistance if the annealing temperature during this interim annealing is

less than 400°C. Moreover, the crystal particle diameter will become too large in a short period of time and properties after the final annealing will deteriorate at an [annealing] temperature exceeding 650°C. Therefore, [the annealing temperature] should be 400 to 650°C. It will be difficult to eliminate bending if the annealing time at this temperature range is less than 10 minutes and therefore, cold drawing will be difficult, while if it exceeds 600 minutes, the crystal particles will be too large and [the procedure] will pose problems economically.

Therefore, a range of 10 to 600 minutes is preferred.

[0024]

The recrystallized product that is obtained after interim annealing is cold drawn to the final plate thickness at a percentage reduction in plate thickness of 20 to 70%. This is because if the percentage reduction in plate thickness is less than 20%, the residual internal stress applied with working will be too low and the increase in final strength and hardness after the final annealing for recrystallization will not occur. On the other hand, if it exceeds 70%, there will be anisotropy of mechanical properties as a result of the formation of an aggregate upon drawing and this in turn will lead to a reduction in workability and an increase in residual internal stress. Therefore, it will not be possible to conduct the final annealing for recrystallization as needed and there will be a reduction in stress-related corrosion and cracking resistance.

[0025]

Next, the recrystallization after cold drawing is accomplished by annealing for 1 to 300 minutes at a temperature of 400 to 700°C. Sufficient

annealing cannot be conducted if the above-mentioned annealing temperature is less than 400°C, while if it exceeds 700°C, the desired crystal particle diameter cannot be obtained (crystal particle diameter will be large) and strength, durability, hardness and stress-related corrosion and cracking resistance will be reduced. Therefore, a range of 400 to 700°C is preferred. If the annealing time within this temperature range is less than 1 minute, sufficient annealing cannot be realized and there will be considerable residual internal stress produced during cold drawing. As a result, there will be a reduction in workability and stress-related corrosion and cracking resistance. If [the annealing time at this temperature range] exceeds 300 minutes, economics will be compromised in the long run. Therefore, a range of 1 to 300 minutes is preferred.

[0026]

Next, the thin plate of alloy obtained after the above-mentioned recrystallization and annealing are further cold drawn by a percentage reduction in plate thickness of 1 to 15%, preferably 3 to 10%. Then low-temperature annealing is performed for 5 to 600 seconds at a temperature of 100 to 400°C. This is done in order to improve strength, stress-related corrosion and cracking resistance and caulking resistance (durability). Caulking resistance is one particular concern when materials are molded into specific shapes and is a property that is very dependent on durability. Therefore, if the percentage reduction in plate thickness with cold drawing is less than 1%, it will be difficult to control plate thickness and an improvement of properties cannot be expected, while if it exceeds 15%, there will be an increase in residual internal stress and

even if low-temperature annealing is performed, there will be no improvement in properties and there will conversely be a reduction in stress-related corrosion and cracking resistance. Therefore, [the percentage reduction in plate thickness with cold drawing] was set at 1 to 15%.

[0027]

On the other hand, if the annealing temperature with low-temperature annealing is less than 100°C, there will not be sufficient recovery and considerable residual internal stress will be produced with the above-mentioned cold drawing. As a result, there will be a reduction in stress-related corrosion and cracking resistance and workability. If it exceeds 400°C, there will be a reduction in strength, durability and hardness. Therefore, it is set at a range of 100 to 400°C. If the annealing time at this annealing temperature is less than 5 seconds, the effects of low-temperature annealing cannot be realized, while if it exceeds 600 seconds, there will be a reduction in strength, durability and hardness, and it will pose an economic problem. Therefore, it was set within a range of 5 to 600 seconds.

[0028]

By working and heat treatment, particularly cold drawing and low-temperature annealing after the final recrystallization annealing, as described in detail above, it is possible to obtain a thin plate of copper-base alloy having a structure wherein the Ni-P compound is finely and uniformly dispersed at the crystal particle boundary surface and within the crystal particles. Moreover, this copper-base alloy has excellent strength, caulking resistance (durability), deep

drawing performance (Erichsen value), and stress-related corrosion and cracking resistance. Therefore, it is ideal as a constituent material for industrial parts, beginning with automobile radiators (with which light weight and high reliability, etc., are possible), and home heat exchangers. Moreover, it can be used as a material for electrical and electronic parts as well.

[0029]

The present invention will be described in further detail with examples. However, the scope of the present invention is not limited to the following examples.

[0030]

[Examples]

The alloys with the chemical components (wt%) in Table 1 (Sample Nos. 1 through 20; Nos. 1 through 6 are alloys of the present invention, Nos. 7 through 17 are comparative alloys, and Nos. 18 through 20 are conventional alloys) were melted using a high-frequency melting furnace and cast into 40 mm x 40 mm x 140 mm ingots. The above-mentioned melting was performed with the melt-casting ambient atmosphere completely shielded by inert gas.

[0031]

[Table 1]

Sample No.	Chemical component value of copper base alloy (wt. %)					Ni/P ratio	Tensile strength (kgf/mm <sup>2</sup> )	Elongation (%)	Erichsen value (mm)	Ammonia cracking time (hr)	Cracking in degraded L.L.C		Comments
	Zn	Ni	Sn	P	Ni + Sn						300 hr	800 hr	
1	9.7	1.23	0.94	0.04	2.17	30.8	37.5	37.9	13.5	48	O	O	Crystal particle diameter 0.025 mm
2	11.4	1.17	1.07	0.05	2.24	23.4	36.2	38.3	13.8	48	O	O	Crystal particle diameter 0.025 mm
3	13.8	0.98	0.90	0.05	1.88	19.6	37.0	40.3	13.5	48	O	O	Crystal particle diameter 0.025 mm
4	12.5	1.01	1.04	0.05	2.05	20.2	36.0	38.4	13.2	48	O	O	Crystal particle diameter 0.025 mm
5	15.3	0.73	0.80	0.04	1.53	18.3	36.8	39.1	13.0	48	O	O	Crystal particle diameter 0.025 mm
6	16.1	0.91	0.82	0.04	1.73	22.8	37.2	39.4	13.4	48	O	O	Crystal particle diameter 0.025 mm
7	2.5	0.99	1.02	0.05	2.01	19.8	33.6	37.4	13.4	72 or more	O	O	Crystal particle diameter 0.025 mm
8	22.2	0.98	1.11	0.05	2.09	19.6	38.1	37.6	12.9	36	O	X	Crystal particle diameter 0.025 mm
9	30.2	0.89	0.92	0.05	1.81	17.8	--	--	--	--	--	--	Cracking with hot drawing
10	13.2	1.10	--	0.06	1.10	18.3	32.5	31.5	12.1	36	O	Δ	Crystal particle diameter 0.025 mm
11	14.1	--	1.05	0.05	1.05	--	32.8	36.8	12.8	18	O	X	Crystal particle diameter 0.060 mm
12	14.5	0.71	0.89	--	1.60	--	33.4	36.8	13.2	24	O	X	Crystal particle diameter 0.025 mm
13	17.5	0.27	0.20	0.05	0.47	5.4	30.5	30.1	11.5	18	Δ	X	Crystal particle



14	15.8	0.37	0.40	0.05	0.77	7.4	33.0	34.1	11.0	24	O	X	diameter 0.025 mm
15	19.5	1.48	1.19	0.05	2.67	29.6	--	--	--	--	--	--	Crystal particle diameter 0.025 mm
16	18.1	1.30	1.11	0.02	2.41	65.0	33.8	37.8	11.8	24	O	X	Cracking with hot drawing
17	13.2	0.81	0.74	0.05	1.55	16.2	31.0	35.2	12.0	24	Δ	X	Crystal particle diameter 0.025 mm
18	18.8	0.31	1.44	0.02	1.75	15.5	--	--	--	--	--	--	Crystal particle diameter 0.025 mm
19	14.9	--	--	--	--	--	29.8	41.8	13.0	12	Δ	X	Cracking with hot drawing
20	21.3	--	--	--	--	--	33.4	50.0	12.4	5 or less	Δ	X	Crystal particle diameter 0.025 mm

[0032]

Next, each ingot was cut to a size of 40 mm x 40 mm x 15 mm after its surface was polished. The ingot was hot drawn at 810 °C to obtain hot-drawn sheets with a thickness of 5 mm. The hot-drawn plates were cold drawn to 1.5 mm and then annealed at a temperature of 500 to 550°C. After annealing, they were quenched with water. They were further washed with acid and cold-drawn to a thickness of 0.55 mm. These were then annealed at a temperature of 400 to 600°C to obtain a crystal particle diameter of 0.025 mm. However, the crystal particle diameter of sample No. 17 only was 0.060 mm. Furthermore, the crystal particle diameter was found with reference to JIS H 0501.

[0033]

Next, these samples were cold drawn to 0.51 mm (drawing rate of 7.3%) and low-temperature annealing was performed for 100 to 600 seconds at 100 to 400°C. In this case, the crystal particle diameter of sample No. 17 was 0.060 mm, but all other samples had a crystal particle diameter of 0.025 mm. After low-temperature annealing, the plates were washed with acid and their surface roughness was adjusted to  $R_{\max}$  of 1.5  $\mu\text{m}$  or less by buff polishing. Furthermore, tensile strength, elongation, the Erichsen value, and stress-related corrosion and cracking resistance of each sample that was obtained were determined and the results are listed in Table 1.

[0034]

Tensile strength, elongation and the Erichsen value were determined in accordance with JIS Z 2241 and JIS Z 2247 (method A). Stress-related

corrosion and cracking resistance was found by diluting commercial aqueous ammonia (25 to 28%) with pure water to approximately 13%, introducing this to the base of a desiccator, placing a sample piece that had been bent into an arch shape so that stress in the middle was 10 kgf/mm<sup>2</sup> inside the desiccator with a support tool, keeping the temperature at a specific temperature while repeatedly removing the sample from the desiccator after a specific amount of time had lapsed and thoroughly rinsing it with water, and finally, observing the sample surface under a stereomicroscope at a magnification of 40 times and determining cracking time.

[0035]

Moreover, a sample piece that had been bent into an arch shape was immersed in degraded L.L.C. (long-life coolant) that had actually been recovered from an automobile, the temperature was kept at 70 to 90°C while removing the piece after 300 hours and after 800 hours and rinsing it thoroughly with water, and then checking for cracks under a stereomicroscope at a magnification of 40 times as an evaluation of stress-related corrosion and cracking resistance. The results are shown in Table 1. The circles in Table 1 indicate samples in which there was only surface discoloration and no cracking occurred, the triangles indicate the samples in which no cracking occurred, but corrosion was marked, and the X's indicate samples in which there was cracking.

[0036]

The method of evaluating the above-mentioned stress-related corrosion and cracking resistance using degraded L.L.C. is an effective method that is

extremely reliable in terms of evaluating the properties of constituent materials of automobile radiators.

[0037]

The following was concluded from the results in Table 1: Alloy Nos. 1 through 6, which are preferred embodiments of the present invention, have excellent tensile strength, elongation, Erichsen value, workability, and soldering performance. Moreover, stress-related corrosion and cracking resistance was good (stress-related corrosion and cracking resistance in an environment where there was contact with L.L.C. was also good). In addition, the alloys were inexpensive and did not use large quantities of expensive metals. Therefore, they are alloys that are an excellent constituent material for so-called heat exchangers, beginning with automobile radiators.

[0038]

In contrast to this, Sample No. 7, which used less Zn than the amount specified by the present invention, had poor strength, and the amount of expensive Cu that was used was high, making cost high. Therefore, it is clearly inappropriate as an industrial material. On the other hand, Sample No. 8, which used the amount of Ni, Sn, and P specified by the present invention, but had a higher Zn content than specified by the present invention, had inferior stress-related corrosion and cracking resistance, and Sample No. 9 (could not be used for production because cracking occurred during hot drawing).

[0039]

Sample No. 10, which did not contain Sn, had poor strength and elongation, and sample No. 11, which did not contain Ni, had poor strength and stress-related corrosion and cracking resistance. Moreover, Sample No. 12, which did not contain P, had poor strength and durability and clearly had inferior stress-related corrosion and cracking resistance. In addition, Sample No. 13, which contained the amount of Zn specified in the present invention, but contained less Ni and Sn than specified by the present invention, had inferior strength and stress-related corrosion and cracking resistance.

[0040]

On the other hand, Sample No. 14, which contained the amounts of Zn, Ni, Sn and P specified by the present invention, but contained less than the amount of Ni + Sn specified by the present invention clearly had inferior strength and stress-related corrosion and cracking resistance. On the other hand, sample No. 15, which contained more Ni + Sn than the amount specified by the present invention, could not be used for production because cracking occurred during hot drawing.

[0041]

Moreover, Sample No. 16, which contained the amount of Zn, Ni, Sn and P specified by the present invention, but had a higher ratio of the weight percentage of Ni/P than specified by the present invention, clearly had low strength and inferior stress-related corrosion and cracking resistance. Moreover, Sample No. 17, which had the amount of Zn, Ni, Sn and P, the amount of Ni + Sn and the Ni/P ratio specified by the present invention, but had a large crystal

particle diameter, had poor strength, elongation and stress-related corrosion and cracking resistance. Furthermore, Sample No. 18, which contained more Sn than specified by the present invention, could not be used for production because cracking occurred during hot drawing.

[0042]

It is clear that sample Nos. 19 and 20, which are conventional brass materials that do not contain Ni, Sn, and P are inferior both in terms of strength and stress-related corrosion and cracking resistance.

[0043]

[Results of the present invention]

The copper base alloy pertaining to the present invention has excellent strength, workability and stress-related corrosion and cracking resistance (including stress-related corrosion and cracking resistance in an environment where there is contact with L.L.C.), particularly as a constituent material for automobile radiators, and can be used to respond to the demand for lightweight, high-reliability, low-cost heat exchangers in various fields.